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CERTIFICATE

This certificate is issued in support of an application for Patent registration in a country outside New Zealand pursuant to the Patents Act 1953 and the Regulations thereunder.

I hereby certify that annexed is a true copy of the Provisional Specification as filed on 17 February 2003 with an application for Letters Patent number 524220 made by KENNETH WILLIAM PATTERSON DRYSDALE.

Dated 16 September 2003.

Neville Harris

Neville Harris
Commissioner of Patents, Trade Marks and Designs

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330 High Street, Lower Hutt and 17 Toop Street, Seaview
PO Box 30687, Lower Hutt, New Zealand or DX SX 11129, Wellington

524220

Patents Form No. 4 Our Ref: RC504213

Patents Act 1953

PROVISIONAL SPECIFICATION

A HEAT PUMP AND A TURBINE FOR USE WITH A HEAT PUMP

I, **KENNETH WILLIAM PATTERSON DRYSDALE,** a citizen of Australia, of 8A Elm Avenue, Belrose, NEW SOUTH WALES, Australia, do hereby declare this invention to be described in the following statement:

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A HEAT PUMP AND A TURBINE FOR USE WITH A HEAT PUMP

TECHNICAL FIELD

The present invention relates to heat pumps and turbines for use with heat pumps, and in particular, but not exclusively, to improved refrigeration or air conditioning methods and apparatus and to turbines for use therewith.

BACKGROUND

Present refrigeration cycles reject heat to the atmosphere. In some cases a portion of the energy which would otherwise be rejected may be recovered from the cycle, thereby increasing the overall efficiency.

OBJECT OF THE INVENTION

It is an object of a preferred embodiment of the invention to provide a heat pump apparatus and/or a method of cooling a heating medium which will increase the utilization of available energy in such apparatus at present.

It is an alternative object of a preferred embodiment of the invention to provide a power generation apparatus and/or a method of generating power which will increase the efficiency of such apparatus at present.

It is an further alternative object of a preferred embodiment of the invention to provide a turbine and/or a method of communicating a fluid to a turbine which will increase the utilization of available energy from such fluid at present.

It is a still further alternative object to at least provide the public with a useful choice.

Other objects of the present invention may become apparent from the following description, which is given by way of example only.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a heat pump apparatus, the apparatus including a first refrigerant within a first refrigerant circuit including;

- First refrigerant compressor means for compressing said first refrigerant in a vapor phase and thereby pumping said first refrigerant around said refrigerant circuit;
- A turbine means downstream of the first refrigerant compressor means for converting a portion of the enthalpy of said refrigerant into kinetic and/or electric energy, thereby expanding and cooling said refrigerant;
- First refrigerant evaporator means downstream of the first turbine means for adding heat from a heating medium to said refrigerant, and thereby evaporating at least a portion of said refrigerant;
- First accumulator means downstream of the first refrigerant evaporator means for accumulating a liquid portion of said refrigerant and allowing a vapor portion of said refrigerant to pass back to said first compressor means, thereby completing the refrigerant circuit;

Preferably, said heat pump apparatus may include a heat exchanger between said turbine means and said first refrigerant evaporator means, said heat exchanger adapted to reject heat from said first refrigerant to a first cooling medium, and to condense at least a portion of said refrigerant.

Preferably, said heat exchanger may be a first condenser means and said first cooling medium may be ambient air.

Preferably, said heat exchanger means may include, or may be thermally connectable to, a second evaporator which is part of a second refrigerant circuit containing a second refrigerant, said second refrigerant circuit adapted to transfer heat from said first refrigerant circuit to said second refrigerant and from said second refrigerant to a second cooling medium.

Preferably, said second cooling medium may be ambient air.

Preferably, said heating medium may be ambient air.

Preferably, the temperature of said second refrigerant entering said second evaporator means may be at least 10°C lower than the temperature of said first refrigerant entering said heat exchanger means.

Preferably, the temperature of said second refrigerant entering said second evaporator may be less than or equal to 0°C.

Preferably, said second refrigerant circuit may include second compressor means and second evaporator means, and a thermoelectric generator means between said second compressor means and said second evaporator means.

According to a second aspect of the present invention, there is provided a power generation apparatus including a fluid supply means adapted to supply fluid at a fluid supply means pressure and a turbine including;

- a rotor chamber;

- a rotor rotatable about a central axis within said rotor chamber;
- at least one outer nozzle including an outer nozzle exit for supplying a fluid flow from said fluid supply means to said rotor to thereby drive said rotor and generate power;
- at least one exhaust aperture extending through said rotor and said rotor chamber to exhaust said fluid from said turbine;
- fluid receiving means operable at a fluid receiving means pressure lower than said fluid supply means pressure, the fluid receiving means adapted to receive fluid from said at least one exhaust aperture; wherein
- the flow of said fluid from said at least one outer nozzle exit is periodically interrupted by at least one flow interrupter means, thereby raising a pressure of said fluid inside said at least one outer nozzle.

Preferably, said power generation apparatus may include at least one fluid storage means between said fluid supply means and said at least one outer nozzle.

Preferably, said fluid supply means may be a positive displacement compressor and said fluid storage means may have a capacity at least equal to a displacement of said positive displacement compressor.

Preferably, said at least one flow interrupter means may substantially stop the flow of said fluid from said at least one outer nozzle exit until the pressure inside said at least one outer nozzle rises to a preselected minimum pressure, which is less than or equal to said fluid supply means pressure.

Preferably, said at least one outer nozzle may be adapted to supply said fluid to said rotor at a sonic or supersonic velocity when the pressure inside said at least one outer nozzle is greater than a threshold pressure which

is between said fluid supply means pressure and said fluid receiving means pressure, and said preselected pressure may be greater than or equal to said threshold pressure.

Preferably, said flow of said fluid from said at least one outer nozzle may be interrupted by said at least one interrupter means for a period sufficient to bring said fluid immediately upstream of said at least one outer nozzle substantially to rest.

Preferably, said at least one exhaust aperture may include a diffuser section adapted to decrease the velocity of said fluid and increase the pressure of said fluid.

Preferably, said rotor may include a plurality of curved outer blades extending radially inward from an outer periphery of said rotor, the curved outer blades adapted to receive said fluid from said at least one outer nozzle and to thereby drive said rotor.

Preferably, said rotor may include at least one inner nozzle means adapted to receive said fluid after it has passed over said outer blades and to provide a force which is at least partially tangential to the direction of rotation of said rotor.

Preferably, the or each said inner nozzle means may direct said fluid in a radially inward direction.

Preferably, the or each said inner nozzle means may be adapted to accelerate said fluid to a speed equal to or above the local speed of sound of said fluid.

Preferably, said rotor may include a plurality of curved inner blades.

Preferably, said rotor may include a plurality of curved outer blades extending radially inwards from an outer periphery of said rotor and a plurality of curved inner blades positioned radially inward of said curved outer blades, said inner blades curved in the same direction as said outer blades.

Preferably said at least one flow interrupter means may include at least one vane connectable to and moveable with an outer periphery of said rotor and adapted to interrupt the flow of said fluid out of said at least one outer nozzle exit when said at least one vane is substantially adjacent said at least one nozzle exit.

Preferably said flow interrupter means may include a plurality of said vanes substantially evenly spaced apart around said outer periphery of said rotor.

Preferably, said fluid may be a refrigerant.

According to a third aspect of the present invention, a method of generating power includes using a power generation apparatus substantially as described in any one of the 16 immediately preceding paragraphs.

According to a fourth aspect of the present invention, there is provided a turbine including;

- a rotor chamber;
- a rotor rotatable about a central axis within said rotor chamber, said rotor including a plurality of outer blades extending radially inward from an outer periphery of said rotor;

- at least one outer nozzle for receiving fluid from a fluid supply means at a fluid supply means pressure and communicating said fluid to said outer blades to thereby drive said rotor;
- at least one inner nozzle means adapted to receive said fluid after it has passed over said outer blades and to accelerate said fluid in a direction such that a reaction force on each said inner nozzle means acts at least partially a direction tangential to the rotation of said rotor;
- at least one exhaust aperture extending through said rotor and said rotor chamber to exhaust said fluid from said turbine; and
- fluid receiving means operable at a fluid receiving means pressure lower than said fluid supply means pressure, the fluid receiving means adapted to receive fluid from said at least one exhaust aperture.

Preferably, the or each said each inner nozzle means may be adapted to accelerate said fluid to a speed equal to or above the local speed of sound of said fluid.

Preferably, the or each said inner nozzle means may direct said fluid in a radially inward direction.

Preferably, said outer blades may be curved and said rotor may include a plurality of curved inner blades positioned radially inward of said curved outer blades, said inner blades curved in the same direction as said outer blades.

Preferably, the flow of said fluid out of said at least one outer nozzle may be periodically interrupted by at least one flow interrupter means, thereby raising the pressure of said fluid inside said at least one outer nozzle.

According to a fifth aspect of the present invention there is provided a method of cooling a heating medium, the method including;

- Using a first refrigerant compressor means to compress a first refrigerant in a vapor phase and to thereby pump said first refrigerant around a first refrigerant circuit;
- Using a turbine means downstream of said first refrigerant compressor means for converting a portion of the enthalpy of said refrigerant into kinetic and/or electric energy, thereby expanding and cooling said first refrigerant;
- Using a first refrigerant evaporator means downstream of said first refrigerant compressor means for adding heat from said heating medium to said first refrigerant, thereby cooling said heating medium and evaporating at least a portion of said first refrigerant;
- Using a first accumulator means downstream of said first refrigerant evaporator means for accumulating a liquid portion of said first refrigerant and allowing a vapor portion of said first refrigerant to pass back to said first compressor means, thereby completing the refrigerant circuit.

Preferably, the method may include providing a heat exchanger between said turbine means and said first refrigerant evaporator means to reject heat from said first refrigerant to a first cooling medium.

Preferably, the method may include using air as said first cooling medium.

Preferably, the method may include thermally connecting said heat exchanger means to a second evaporator which is part of a second refrigerant circuit containing a second refrigerant and exchanging heat from said first refrigerant circuit to a second cooling medium.

Preferably, the method may include using ambient air as said second cooling medium.

Preferably, the method may include using ambient air as said heating medium.

Preferably, the method may include adapting said first and second refrigerant circuits such that the temperature of said second refrigerant entering said second evaporator means is at least 10°C lower than the temperature of said first refrigerant entering said heat exchanger means.

Preferably, the method may include adapting said second refrigerant circuit so that the temperature of said second refrigerant entering said second evaporator is substantially less than or equal to 0°C.

Preferably, the method may include providing said second refrigerant circuit with second compressor means and second evaporator means, and using a thermoelectric generator means between said second compressor means and said second evaporator means.

According to a sixth aspect of the present invention, there is provided a method of communicating a fluid supplied by a fluid supply means at a fluid supply means pressure to a turbine rotor, the method including;
providing at least one nozzle for communicating said fluid from said fluid supply means to said turbine rotor, to thereby drive said rotor,
the method further including providing at least one flow interrupter means to periodically interrupt the flow of said fluid out of said at least one nozzle, thereby raising the pressure of said fluid inside said at least one nozzle to a preselected minimum pressure which is less or equal to said fluid supply means pressure.

Preferably, the method may include providing at least one fluid storage means between said fluid supply means and said at least one nozzle.

Preferably, said fluid supply means may be a positive displacement compressor and said fluid storage means may a capacity at least equal to a displacement of said positive displacement compressor.

Preferably, the method may include operating said at least one interrupter means for a period sufficient to bring said fluid immediately upstream of said nozzle substantially to rest.

According to a seventh aspect of the present invention, a heat pump and/or a method of cooling a heating medium is substantially as herein described with reference to the accompanying figures.

According to a further aspect of the present invention, a power generation apparatus and/or a method of generating power is substantially as herein described with reference to the accompanying figures.

According to a further aspect of the present invention a method of supplying fluid to a turbine is substantially as herein described with reference to the accompanying figures

According to a still further aspect of the present invention, a turbine (as herein defined), and/or a method of generating power, is substantially as herein described with reference to the accompanying figures.

Further aspects of the invention, which should be considered in all its novel aspects, will become apparent from the following description given by way of example of possible embodiments of the invention.

BRIEF DESCRIPTION OF DRAWINGS

FIGURE 1. Shows a block diagram of a heat pump apparatus according to one embodiment of the present invention.

FIGURE 2. Shows a block diagram of a heat pump according to a second possible embodiment of the present invention.

FIGURE 3. Shows very diagrammatically a sectional view of a power generation apparatus including first and second interrupter means according to a second aspect of the present invention, with the turbine housing removed for clarity.

FIGURE 4. Shows very diagrammatically a sectional view of a turbine according to another possible embodiment of the present invention, with the turbine housing removed for clarity.

FIGURE 5. Shows very diagrammatically a sectional view of another embodiment of a turbine with the turbine housing removed for clarity.

BRIEF DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

The present invention is described herein with reference to its use as a refrigeration cycle. Those skilled in the art will recognise that the heat pumping circuit described may have a variety of uses, for example air conditioning or heating. Those skilled in art will also recognise that the term "refrigerant" is used to describe any working fluid suitable for use in such a circuit or cycle.

A simple refrigeration circuit of the prior art (not shown) may include, in order, a compressor, a condenser, a receiver, a throttling or Tx valve, an evaporator and an accumulator.

Warm refrigerant vapour enters the compressor, which as a result of a work input, compresses the vapour thus raising its temperature and pressure. A significant portion of the work input into the compressor re-appears as the heat of compression thus superheating the refrigerant.

The superheated refrigerant vapour thus has its temperature elevated above that of the ambient temperature of the environment and enters a heat exchanger called a condenser. Heat is then extracted from the refrigerant by the environment which is at a lower temperature. The heat exchange continues until sufficient heat is removed from the refrigerant to cause a change of state from hot vapour to hot liquid.

The hot refrigerant then enters a reservoir, usually referred to as a "receiver" which has a sufficiently large volume to support the requirements of the circuit and withstand the high pressure in the discharge line of the compressor. The hot, high pressure refrigerant liquid then enters the throttling

device, hereinafter referred to as a "Tx valve", which reduces its pressure and temperature. The drop in pressure causes the liquid refrigerant to expand, flash to vapour and acquire heat. The heat absorbing refrigerant vapour is passed through a heat exchanger or "evaporator " where it absorbs heat from ambient temperature air which is typically blown across its surfaces by a fan, cooling the air and thereby providing the refrigeration effect. The temperature and enthalpy of the refrigerant vapour is thus progressively increased as heat is added.

The heat laden working refrigerant vapour is then passed into an accumulator which has an internal structure designed to allow any remaining liquid to boil off prior to entering the compressor and completing the circuit.

Some embodiments of the prior art may combine two of the above elements into a single device, for example some compressors may also include an accumulator, but the function of each element is usually present in the circuit.

The operation of prior art refrigeration circuits is well known to those skilled in the art and will not be described in further detail.

The term "turbine" is used herein to describe a device which converts energy from a fluid stream into kinetic and/or electrical energy. Those skilled in the art will appreciate that where the energy is required in electrical form the turbine may include a suitable electric power generator or alternator.

Referring next to Figure 1 a heat pump apparatus of the present invention includes a first refrigerant circuit 100 which includes a first compressor 1 feeding a refrigerant in a vapor phase into a turbine 300. The turbine 300 may convert energy from the refrigerant into kinetic and/or

electrical energy, thereby lowering the temperature and pressure of the first refrigerant.

In some embodiments the turbine 300 may be designed to avoid cooling the refrigerant to the point where drops of liquid refrigerant form within the turbine 300, as this may damage the working surfaces within the turbine 300, although in alternative embodiments the turbine 300 may be adapted to allow condensation of the refrigerant without damage to the turbine 300.

A heat exchanger 8 may be necessary downstream of the turbine 300 in order to ensure that the first evaporator 5 is supplied with a sufficient supply of relatively low temperature refrigerant to absorb a required amount of heat, although in some embodiments the turbine 300 may drop the temperature and pressure of the refrigerant sufficiently for an heat exchanger 8 to be unnecessary.

Those skilled in the art will appreciate which qualities of the refrigerant passing through the first evaporator 5 will affect the heat flow into the first evaporator 5.

The refrigerant leaving the first evaporator 5 may, if needed, proceed through a first accumulator 6 before returning to the first compressor 1. Those skilled in the art will appreciate that a receiver 3 may not be required as the accumulator 6 may provide a sufficient refrigerant reservoir.

The heat exchanger 8 may be a traditional condenser, that is, it may reject heat to the ambient air, or, if required, the heat exchanger 8 may exchange heat with a second evaporator 5A of a second refrigerant circuit 200 containing a second refrigerant, as illustrated in Figure 2, in order to remove sufficient heat from the first refrigerant circuit 100.

Referring next to Figure 2, in a preferred embodiment the second refrigerant circuit 200 may include a second evaporator 5A, second accumulator 6A, second compressor 1A, second condenser 8A, second receiver 3A and Tx valve 4A, arranged in the same order and performing the substantially same function as a refrigeration circuit of the prior art. The second refrigerant may preferably have a boiling point of less than 10°C, more preferably around 0°C. A suitable second refrigerant may be R22, R134A or R123, although those skilled in the art will appreciate that other refrigerants with suitably low boiling points may be used.

The heat absorbed by the second evaporator 5A of the second refrigeration circuit 200 may be rejected to a second cooling medium, preferably ambient air, by the second condenser 8A. In a preferred embodiment the temperature of the second refrigerant entering the second condenser 8A may be above 30°C, and preferably around 60°C. The temperature of the second refrigerant entering the second evaporator 5A is preferably at least 10°C lower than the temperature of the first refrigerant entering the first heat exchanger 8.

In some embodiments one or more thermoelectric generators 9 positioned between the second compressor 1A and second condenser 8A may use refrigerant from the second refrigerant circuit 200 as a hot heat sink in order to generate electricity. Thermoelectric generators 9 may be particularly useful if the refrigerant used is R123, as the condensing temperature may be as high as 180°C and the evaporation temperature between 35°C and 10°C, thereby providing a large temperature differential.

In a preferred embodiment the speed of one or both of the compressors 1, 1A may be adjusted to maximize the coefficient of performance of one or

both of the refrigerant circuits 100, 200. The refrigerant in the second refrigerant circuit 200 may also be bypassed around the Tx valve 4A and second evaporator 5A if necessary, for example to balance the mass flow and heat exchange requirements of the second refrigerant circuit 200. This may, for example, be controlled by a microprocessor.

Those skilled in the art will appreciate that by positioning the turbine 300 immediately downstream of the first compressor 1, the turbine 300 may convert a portion of the energy which would otherwise be rejected from the system by the heat exchanger 8 or condenser or the prior art into useful electric or kinetic energy.

Referring next to Figure 3, a turbine 300, suitable for use with the heat pump apparatus described above in order to generate power, may include at least one outer nozzle 400 mounted in housing of the turbine (not shown) which has a converging/diverging section (not shown) adapted to accelerate the refrigerant flowing through it to sonic or supersonic speeds.

The turbine 300 is described below with reference to its use as part of a heat pump circuit, such as those described above, in which the working fluid is refrigerant, but those skilled in the art will appreciate that other applications are possible and that the working fluid may in these embodiments be some other suitable gaseous fluid.

The flow from the or each outer nozzle 400 may be periodically interrupted by one of two interruption means.

A first interruption means may include one or more vanes 10 located proximate the outer periphery of the turbine rotor 500 and adapted to

substantially prevent refrigerant from flowing from an outer nozzle 400 when the vane 10 is proximate the outer nozzle outlet 12.

A second interruption means 11 may include an electronically operated valve proximate the outer nozzle outlet 12. The second interruption means 11 may have an extremely fast response and may, for example, be similar in operation to an electronically operated common rail diesel injector.

A refrigerant storage vessel 13 may be located proximate the outer nozzle entrance 14. If the first compressor (not shown) is a positive displacement compressor then the refrigerant storage vessel 13 may preferably have an internal volume at least equal to a single displacement of the first compressor. The refrigerant storage vessel 13 may have any capacity greater than the displacement of the first compressor.

Preferably the refrigerant storage vessel 13 may be an insulated spherical container located as close as possible to the outer nozzle entrance 14.

The interrupters 10, 11 may stop the flow of refrigerant sufficiently rapidly to cause an adiabatic pressure rise in the outer nozzle 400 without a corresponding increase in enthalpy. The flow of refrigerant may be interrupted for a period which is sufficiently long for the pressure inside the outer nozzle 400, and more preferably inside the refrigerant storage vessel 13, to reach a preselected minimum pressure which is less than the pressure supplied by the first compressor. This pressure may be selected to ensure that when the interrupters 10, 11 are both open, the refrigerant exits the outer nozzle 400 at sonic or supersonic speeds.

The period for which the or each vane 10 stops the flow from the outer nozzle 400 depends on the circumference of the turbine rotor 500, the rotational speed of the rotor 500 and the length of the vane 10 in the circumferential direction. In some embodiments this period may be sufficiently long that a second interrupter means 11 is not required. In most embodiments however, a second interrupter means 11 will be required at least at high rotational speeds in order to interrupt the flow for a sufficient period.

In other embodiments the second interrupter means 11 may be capable of closing sufficiently rapidly that the vanes 10 are not necessary, but in many cases the vanes 10 may provide a relatively simple interrupter means which is capable of closing the outer nozzle outlet 12 at high speed.

The refrigerant storage vessel 13 and interrupter means 10, 11 may assist in increasing the amount of energy recovered from the refrigerant while still allowing sufficient refrigerant to flow to provide an adequate overall heat absorption effect from a refrigerant circuit.

The Applicant believes that when the interrupter closes, the mass flow of the working fluid, in this case refrigerant, between the outer nozzle 400 and the high pressure source feeding the outer nozzle 400, which in most cases may be a first compressor, may decrease towards zero, and the pressure in the refrigerant storage vessel 13 and outer nozzle entrance 14 may rise towards the maximum pressure of the discharge line of the first compressor.

This upward pressure excursion is a function of the decrease in mass flow rate of the fluid. When the mass flow rate is zero then the pressure difference across the outer nozzle 400 may be substantially zero, therefore the pressure at the outer nozzle entrance 14 is at a maximum and the kinetic energy change in the refrigerant is zero and the enthalpy change is zero. Thus, when the refrigerant is stopped the pressure rises at the outer nozzle

entrance 14 to the maximum value provided by the compressor and the enthalpy change is zero.

The Applicant believes that if the period of time when the refrigerant is interrupted is short in comparison to the time in which the refrigerant is allowed to flow, then the deterioration in overall mass flow in a refrigerant circuit of which the turbine 300 is a component will be minimal.

The Applicant also believes that an advantage of stopping the mass flow through the outer nozzle 400 is that, if the period of the flow interruption is sufficiently short and the increase in pressure of the refrigerant occurs substantially adiabatically, there will be no change in the enthalpy of the stationary refrigerant in the outer nozzle 400.

The Applicant believes that if the increase in internal energy during the time when the refrigerant is stationary and the refrigerant is compressed compensates for the expansion of the refrigerant and its depletion of work during the time when the mass flow is flowing, which may be achieved by properly selecting the ratio of time during which the refrigerant flows to time in which the refrigerant is interrupted, then the enthalpy extraction process may become substantially continuous. The Applicant believes that this may result in an increased extraction of enthalpy from the working fluid over systems of the prior art.

Those skilled in the art will also appreciate that the timing of the second interrupter 11 may be controlled by a processing means (not shown). The processing means may receive information on the angular position of the turbine rotor 500 from any suitable means, but preferably from a hall effect sensor or similar mounted on the turbine housing (not shown) which may sense a suitable index mark on the rotor 500.

The processing means may also vary the speed of the turbine rotor 500 by varying the opening times of the second interrupter 11.

Figure 4 shows an alternative turbine rotor 500A which may be suitable for use with the turbine 300 described above.

In one embodiment the rotor 500A may include a plurality of curved outer blades 15 extending radially inwards from an outer periphery of the rotor 500A towards one or more exhaust aperture 16. These outer blades 15 may be arranged to form an impulse or pelton wheel type rotor such as are well known to those skilled in the art.

The or each exhaust aperture 16 may extend through the rotor 500A substantially parallel its central axis. Preferably, the rotor 500A may include a single, centrally located exhaust aperture 16 adapted to decrease the speed and increase the pressure of the refrigerant flowing through it, that is, the exhaust aperture 16 may act as a diffuser. Preferably the exhaust aperture 16 may include a plurality of radially inwardly extending fingers 16A. The cross-sectional area between the fingers 16A should be less than the throat of the at least one outer nozzle 400 or, if present, the at least one inner nozzle means 17 described immediately below.

In some embodiments the rotor 500A may further include at least one inner nozzle means 17 adapted to receive the refrigerant after it has passed over the outer blades 15. In a preferred embodiment the inner nozzle means 17 may be removably mounted on an inner nozzle mounting means 19, possibly be a thread (not shown) on the outside of the inner nozzle mounting means 19 engaging a thread on an inner surface of a complimentary aperture in the inner nozzle mounting means 19.

The inner nozzle mounting means 19 may preferably be a substantially ring shaped member. The inner nozzle mounting means 19 may also function to channel the refrigerant exiting the outer blades 15 into the inner nozzle means 17 by sealing the path between the outer blades 15 and the exhaust aperture 16.

The or each inner nozzle means 17 may have a converging/diverging inner section 18 adapted to accelerate the refrigerant to sonic or supersonic speeds, thereby further reducing the pressure and temperature of the fluid.

The or each inner nozzle means 17 may be orientated such that the reaction force exerted by the refrigerant as it accelerates through the inner nozzle means 17 acts at least partially in the direction of rotation of the rotor 500A, that is, a vector representing the reaction force has a tangential component which drives the rotor in the same direction as the outer blades 15.

Referring next to Figure 5, in one embodiment the rotor 500B may include a plurality of curved inner blades 20 extending radially outward from the exhaust aperture 16. If used in conjunction with the outer blades 15 described above, the inner blades 20 may preferably be curved in the same direction to the curvature of the outer blades 15 in order to maximize the energy extracted from the refrigerant.

In some embodiments, the outer blades 15 and inner blades 20 described above may be used in combination either with or without the inner nozzle means 17.

If only outer blades 15 in a pelton wheel type arrangement are used then the exhaust aperture 16 may be relatively large and may not need to act

as a diffuser. Accordingly the fingers 16A may be omitted and the exhaust aperture 16 may be substantially round.

Interrupter means such as the vanes 10 described above may be provided at the outer periphery as described above with reference to Figure 4, but the turbine 300 may also be used in applications which do not utilise interrupters.

Referring to Figures 1, 2 and 3, a suitable control means (not shown), such as a microprocessor or computer, may vary one or more of the speed of the first compressor 1, the speed of the second compressor 1A, and the timing of the second interrupter 11 to optimize a selected parameter of each refrigerant circuit. In some embodiments the heat absorbed by the first evaporator 5 may be the selected parameter, while in other embodiments the total power input one or both of the compressors 1, 1A may be the selected parameter.

Those skilled in the art will appreciate that the turbine 300 described above may have application outside refrigerant circuits wherever it is desirable to convert energy from a suitable gaseous working fluid to kinetic and/or electric energy.

Where in the foregoing description, reference has been made to specific components or integers of the invention having known equivalents then such equivalents are herein incorporated as if individually set forth.

Although this invention has been described by way of example and with reference to possible embodiments thereof, it is to be understood that modifications or improvements may be made thereto without departing from the scope or spirit of the invention.

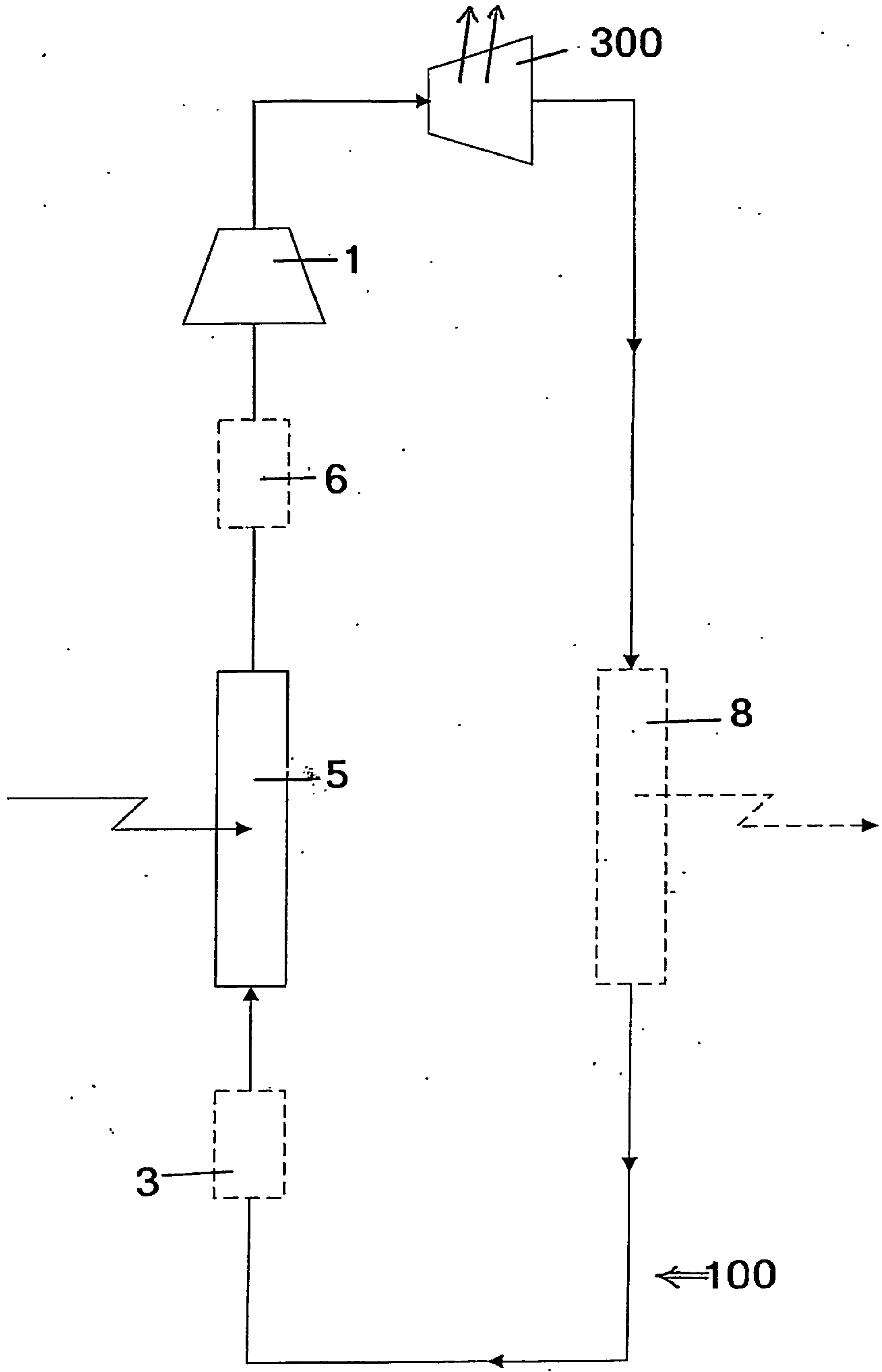

FIGURE 1

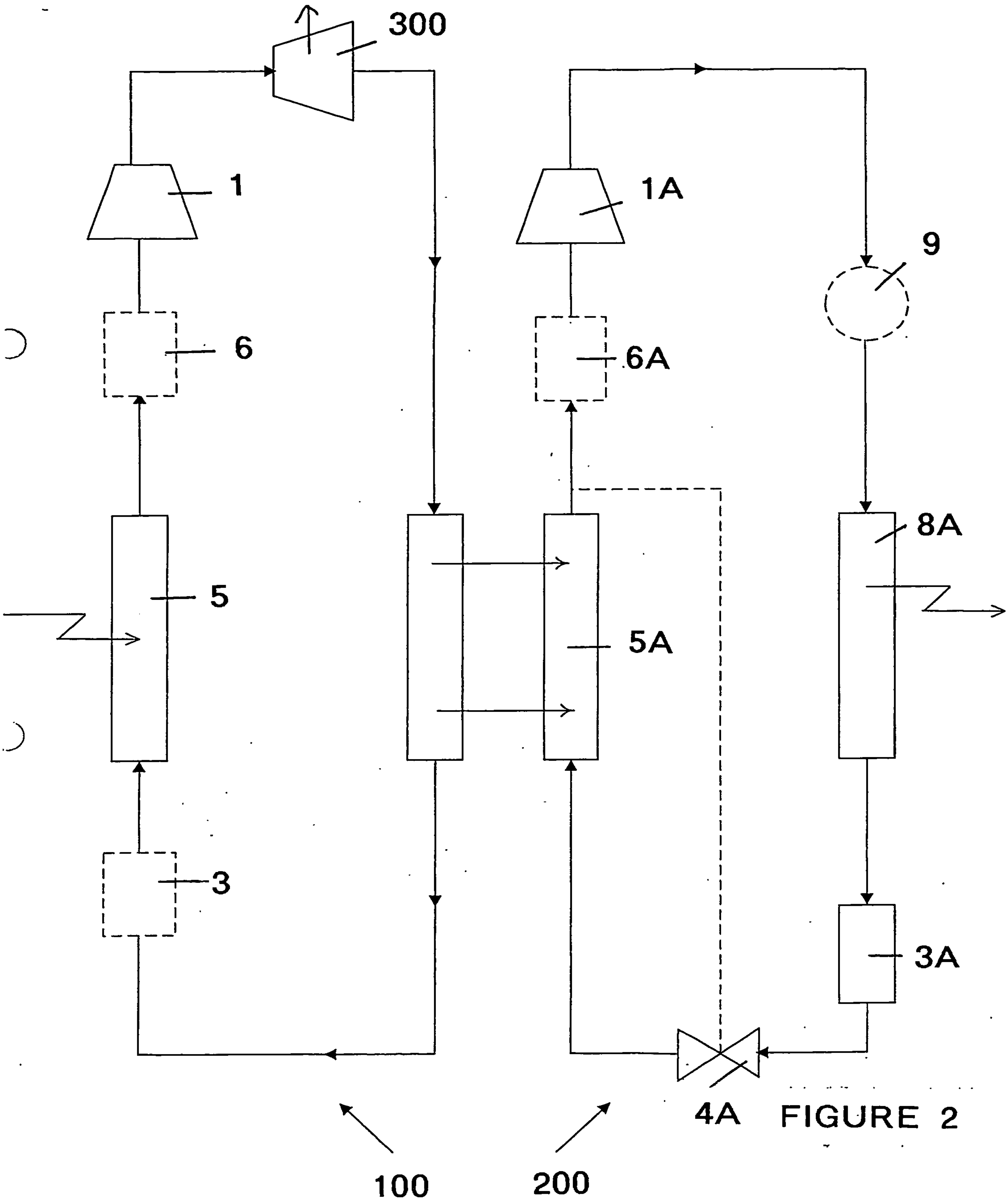

FIGURE 2

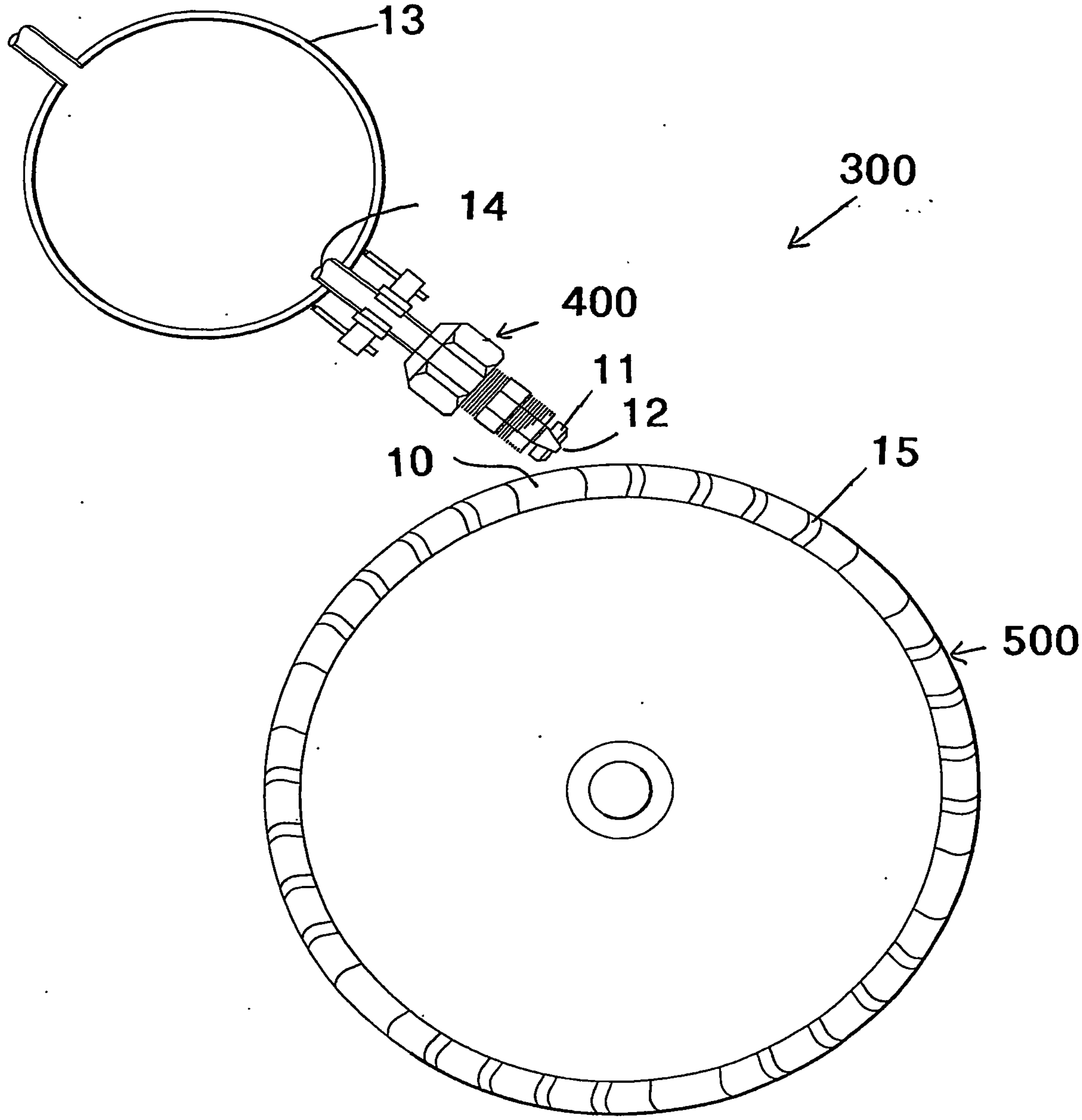

FIGURE 3

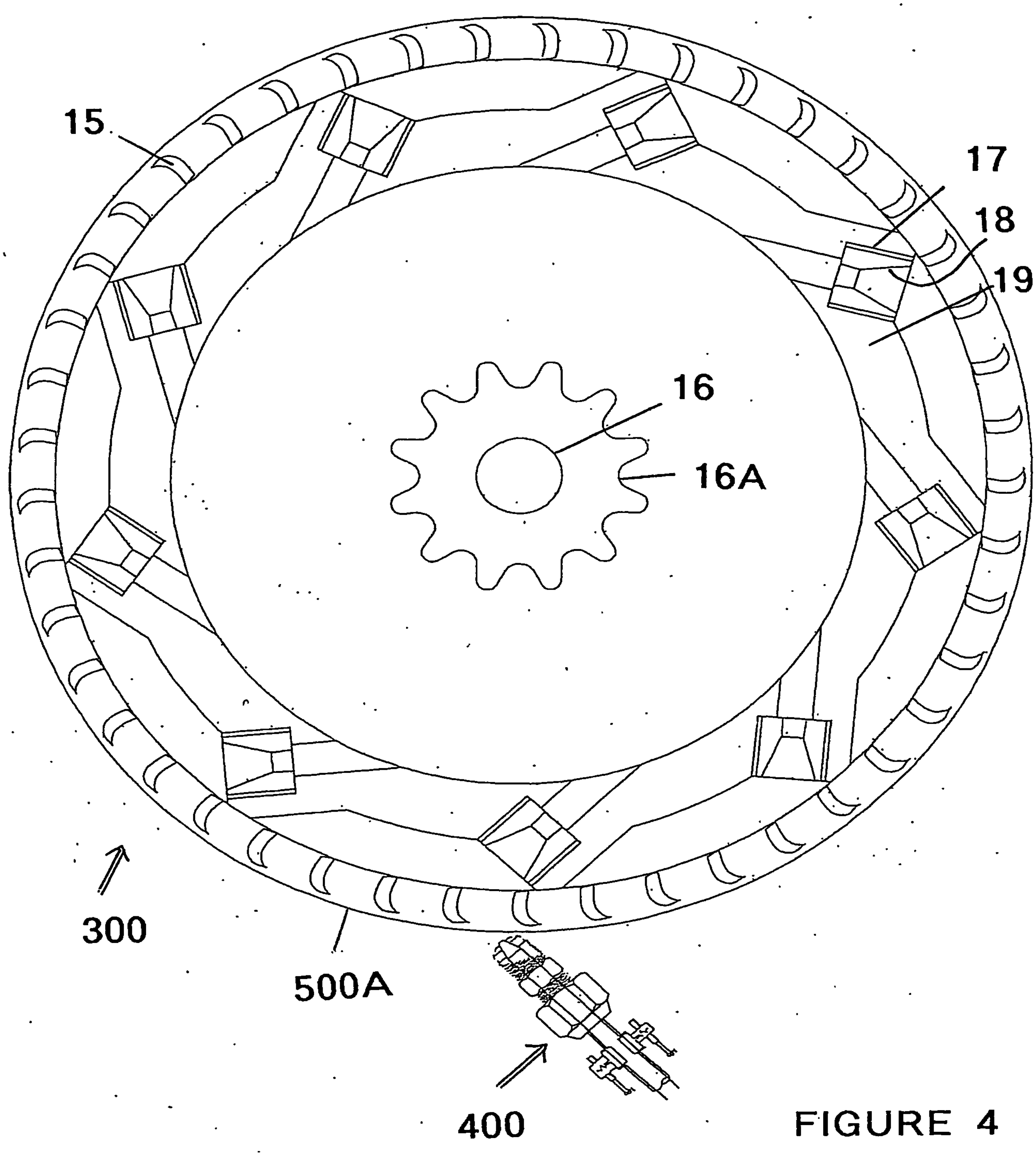

FIGURE 4

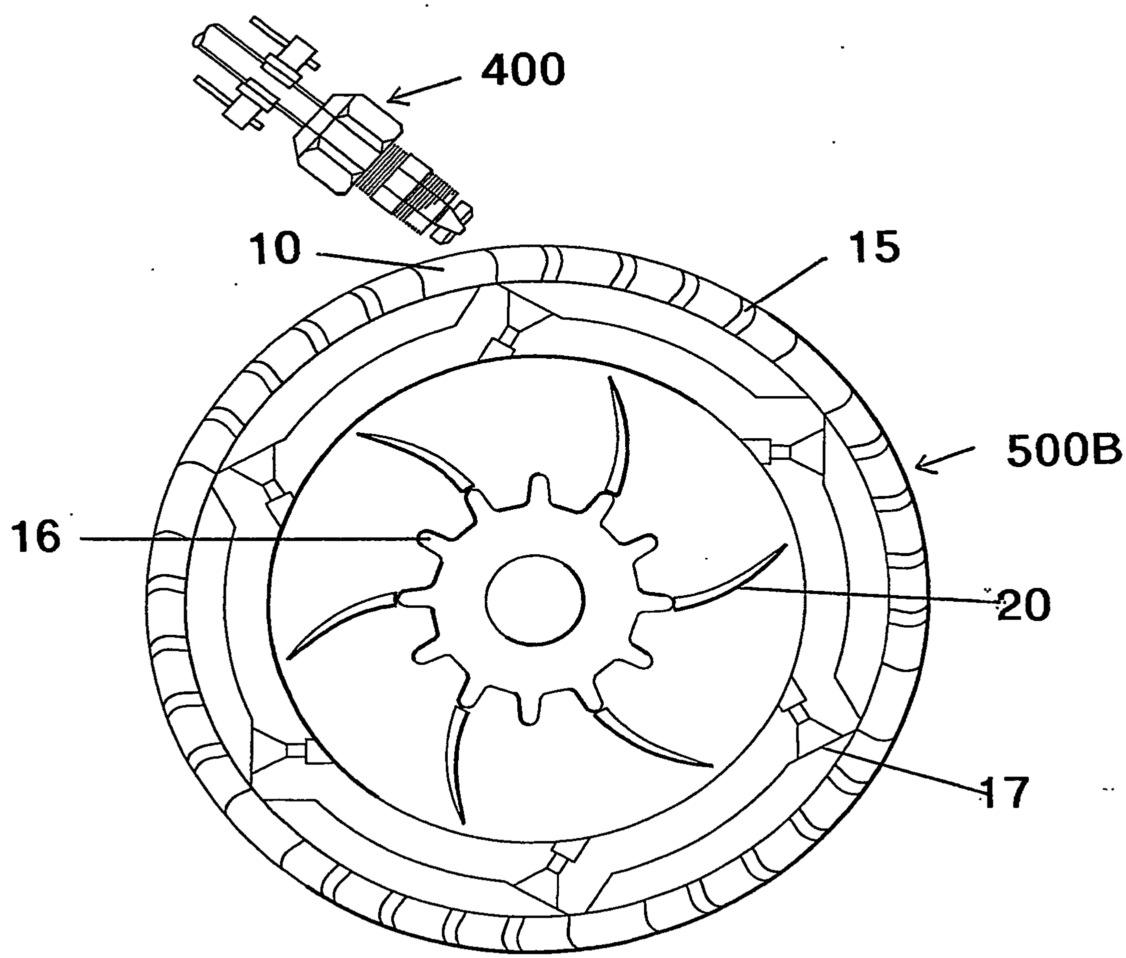

FIGURE 5